POPULATION ASSESSMENT AND POTENTIAL FUNCTIONAL ROLES OF NATIVE MUSSELS IN SELECT REACHES OF THE UPPER HUDSON RIVER:

2013 REMEDIAL INJURY PILOT STUDY

HUDSON RIVER NATURAL RESOURCE DAMAGE ASSESSMENT

HUDSON RIVER NATURAL RESOURCE TRUSTEES

STATE OF NEW YORK

U.S. DEPARTMENT OF COMMERCE

U.S. DEPARTMENT OF THE INTERIOR

PUBLIC RELEASE VERSION*

FINAL

September 10, 2014

Available from:
U.S. Department of Commerce National Oceanic and Atmospheric Administration
Hudson River NRDA, Lead Administrative Trustee, Office of Response and Restoration, Assessment and Restoration Division 1305 East-West Highway, Rm 10219 Silver Spring, MD 20910-3281

* Names of certain individuals and affiliations have been removed to maintain confidentiality.

TABLE OF CONTENTS

EXECUTIVE SUMMARY 3
1.0 BACKGROUND 3
2.0 INTRODUCTION 4
3.0 PURPOSE AND OBJECTIVE 4
4.0 METHODS 4
5.0 QUALITY ASSURANCE/QUALITY CONTROL 5
6.0 SPECIAL PROVISIONS 5
7.0 LITERATURE CITED 5
Appendix A: 2013 Pilot Study Plan 7

EXECUTIVE SUMMARY

Natural resources of the Hudson River have been contaminated through past and ongoing discharges of polychlorinated biphenyls (PCBs). The Hudson River Natural Resource Trustees – New York State, the U.S. Department of Commerce, and the U.S. Department of the Interior – are conducting a natural resource damage assessment (NRDA) to assess and restore those natural resources injured by PCBs.

The Hudson River PCBs Superfund Site (the "Site") extends about 200 miles between Hudson Falls and the Battery in New York City. A 40-mile stretch of the freshwater non-tidal Upper Hudson River, from Fort Edward to Troy, NY, is the site of an extensive PCB federal Superfund remediation project being conducted by The General Electric Company pursuant to the Record of Decision issued by EPA in 2002. Dredging to remove PCBs, followed by capping or backfilling of dredged areas, began in 2009 and is ongoing. The Hudson River Natural Resource Trustees have been assessing PCB contamination and injuries to natural resources in the Hudson River.

Trustees have decided to survey native mussel populations to assess potential injuries to these resources. This work will also be used to help determine whether future studies will be performed, and if so, to help in their design. The Trustees are now releasing in this document the Work Plan for the 2013 pilot study.

1.0 BACKGROUND

Freshwater pearly mussels are among the most imperiled groups of animals in North America (Strayer et al. 2004). Almost 300 species of freshwater mussels have been described as endemic to North America, representing the greatest diversity of these mussels in the world. Of these species, 13% are listed as extinct and 66% of the remaining species are ranked as vulnerable, imperiled, or critically imperiled (Master et al. 2000). Historically, 51 species of mussels have been described in the state of New York. Currently, 38 species are listed by the New York State Department of Environmental Conservation (NYSDEC) as extinct, threatened, or endangered, or are designated as Species of Greatest Conservation Need (http://www.dec.ny.gov/animals/9406.html). Because mussel populations in many rivers and lakes in the State of NY have never been surveyed and recorded, important populations of mussel species may exist, but have yet to be characterized or described. Such is the case for the Upper Hudson River (north of Troy, NY) where there is knowledge that abundant populations of mussels exist, but documentation of population sizes and species diversity is limited. Strayer (2012) noted that there could be 19 species of mussels present in the Hudson River between Corinth and Troy, NY.

The diversity and abundance of freshwater fauna provide critical functions and services in these ecosystems. An important group of organisms for the function of freshwater systems is the native pearly mussels (Bivalvia: Unionidae). Mussels can be the most abundant benthic organisms in terms of biomass in some systems, often occurring in high-density beds of multiple species (Strayer et al. 1999; Raikow and Hamilton 2001). Freshwater mussels serve as couplers of nutrient and energy flows between pelagic and benthic communities (Welker and Walz 1998; Raikow and Hamilton 2001; Nalepa et al. 1991; Vaughn and Hakenkamp 2001), particularly in moving water where materials would otherwise be transported downstream. In addition, mussel shells provide habitat for other benthic organisms (Sephton et al. 1980; Beckett et al. 1996) and epiphyton (Vaughn and Hakenkamp 2001; Gutiérrez et al. 2003) and a potential source of food for consumers (Owen et al. 2011).

These services are important for the preservation of clean freshwater ecosystems that provide drinking water and recreational opportunities for residents and visitors to New York. Changes to the diversity, long-term viability, and abundance of the native mussel community may alter the function and services

that these communities perform. In the Upper Hudson River, sediment (along with the associated mussel community) has been removed since the dredging project began in 2009, and large areas of the native mussel community have presumably already been altered. The remediation will ultimately remove approximately 2.7 million cy of sediment from River Sections 1, 2 and 3 (USEPA 2002).

2.0 INTRODUCTION

Dredging activities in the Upper Hudson River are removing sediment along with the associated mussel communities, which are not being replaced as part of the remedy for the Hudson River PCBs Superfund Site. Since the dredging project began in 2009, large areas of the native mussel community have presumably already been altered.

The pilot study was conducted to collect information about mussels in the Upper Hudson River where dredging had not yet occurred. Areas targeted for remediation and areas not targeted for remediation were sampled. Surveys in 2013 were planned for the Fort Miller and Northumberland Pools and potentially other pools if time permitted and dredging had not yet commenced. Surveys were completed in the Fort Miller Pool and Stillwater Pool. Dredging started in the Northumberland Pool prior to initiation of the 2013 mussel pilot study.

The information collected will serve to inform injury quantification and restoration planning relating to mussels adversely impacted by remedial work. Results should inform the determination of impacts of the remedy upon natural resources, spatial/temporal recovery of impacted mussel beds, and establishment of (replacement) mussel beds.

3.0 PURPOSE AND OBJECTIVE

Surveys performed in 2013 were designed to quantitatively survey and characterize the species composition, population size, relative abundance, and population structure (in terms of age and length) of mussels within each surveyed section of river.

4.0 METHODS

On behalf of the Trustees, Principal Investigators (PIs) conducted a pilot study in 2013 to quantitatively survey and characterize the species composition, population size, relative abundance, and population structure (in terms of age and length) of mussels within each surveyed section of the Hudson River. This information will be used to estimate species composition, relative abundance, population size, population structure and ecological services of mussel communities in the Upper Hudson River prior to and after remedial actions.

This study was conducted pursuant to a work plan entitled "Population Assessment and Potential Functional Roles of Native Mussels in Select Reaches of the Upper Hudson River: 2013 Remedial Injury Pilot Study" contained in Appendix A. The Trustees are now releasing that Work Plan (Appendix A) in this document.

5.0 QUALITY ASSURANCE/QUALITY CONTROL

This study is being conducted in accordance with the Quality Assurance Management Plan for the Trustees' Hudson River NRDA (Hudson River Natural Resources Trustees 2002). The NYSDEC Hudson River NRDA Case Manager, working under the direction of the Hudson River Trustee Council, has overall project oversight responsibility. The Study Plan and Standard Operating Procedures for this study were developed to provide detailed and explicit instruction for the Field Teams to follow when collecting study data. Data developed in this study must meet standards of precision, accuracy, completeness, representativeness, comparability, and sensitivity, and be consistent with sound scientific methodology appropriate to the data quality objectives.

All samples collected under this Study Plan will be maintained under chain-of-custody upon collection, and through processing, storage and shipment to the testing laboratory, analytical laboratory or archive facility. Analysis will be by appropriate methods approved by the Trustees. Quality assurance and quality control are described in greater detail in Appendix A.

6.0 SPECIAL PROVISIONS

Permission will be required to enter private lands or lands under the jurisdiction of State agencies or authorities other than New York State Department of Environmental Conservation to access certain locations on the Hudson River. Appropriate collection permits were obtained prior to conducting the pilot study.

7.0 LITERATURE CITED

Beckett, D.C., Green, B.W., Thomas, S.A., and Miller, A.C. 1996. Epizoic invertebrate communities on upper Mississippi River unionid bivalves. American Midland Naturalist 135: 102-114.

Gutiérrez, J.L., Jones, C.G., Strayer, D.L., and Iribarne, O.O. 2003. Mollusks as ecosystem engineers: the role of shell production in aquatic habitats. Oikos. 101: 79-90.

Hudson River Natural Resource Trustees. 2002. Hudson River Natural Resource Damage Assessment Plan. September 2002. U.S. Department of Commerce, Silver Spring, MD.

Master, L.L., Stein, B.A., Kutner, L.S., and Hammerson, G.A. 2000. Vanishing assets: Conservation status of U.S. species. Pages 93-118 in Stein, B.A., Kutner, L.S., Adams, J.S., eds. Precious Heritage: The Status of Biodiversity in the United States. Oxford (United Kingdom): Oxford University Press.

Nalepa, T.F., Gardner, W.S., and Malczyk, J.M. 1991. Phosphorus cycling by mussels (Unionidae: Bivalvia) in Lake St Clair. Hydrobiologia. 219: 230-250.

Owen, C.T., M.A. McGregor, G.A. Cobbs, J.E. Alexander. 2011. Muskrat predation on a diverse unionid mussel community: impacts of prey species composition, size and shape. Freshwater Biology 56: 554-564.

Raikow, D.F. and Hamilton, S.K. 2001. Bivalve diets in a Midwestern U.S. stream: A stable isotope enrichment study. Limnology and Oceanography 46(3): 514-522.

Sephton, T.W., Paterson, C.G., and Fernando, C.H. 1980. Spatial interrelationships of bivalves and nonbivalve benthos in a small reservoir in New Brunswick, Canada. Canadian Journal of Zoology 58: 852-859.

Strayer, D.L., Downing, J.A., Haag, W.R., King, T.L., Layzer, J.B., Newton, T.J., and Nichols, S.J. 2004. Changing perspectives on Pearly Mussels, North America's most imperiled animals. BioScience. 54(5):429-439.

Strayer, D.L., Caraco, N.F., Cole, J.J., Findlay, S., and Pace, M.L. 1999. Transformation of freshwater ecosystems by bivalves. BioScience. 49: 19-27.

Strayer, D.L. 2012. An introduction to the pearly mussels of the middle Hudson River (Corinth to Troy). A presentation to the Hudson River PCBs Superfund Site Community Advisory Group on June 28, 2012.

Vaughn, C.C. and Hakenkamp, C.C. 2001. The functional role of burrowing bivalves in freshwater ecosystems. Freshwater Biology 46: 1431-1446.

Welker, M. and Walz, N. 1998. Can mussels control the plankton in rivers? – a planktological approach applying a Langrangian sampling strategy. Limnology and Oceanography 43:753-762

USEPA. 2002. Hudson River PCBs Site New York Record of Decision, February 2002. http://www.epa.gov/region2/superfund/hudson/rod.htm (accessed May 5, 2014).

APPENDIX A

POPULATION ASSESSMENT AND POTENTIAL FUNCTIONAL ROLES OF NATIVE MUSSELS IN SELECT REACHES OF THE UPPER HUDSON RIVER:

2013 REMEDIAL INJURY PILOT STUDY

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY 9

2. PROBLEM STATEMENT 9

3. BACKGROUND 9

4. METHODS 10

5. SCHEDULE 12

6. REFERENCES 12

7. APPENDICES 14

Appendix 1: Health and Safety Protocol 14

Appendix 2: Chain of Custody Form 16

Appendix 3: Hudson River 2013 Data Sheet 17

Appendix 4 : Dive Boat Data Sheet 18

Appendix 5: Protocol for Sampling Native Mussels in Upper Hudson River 19

EXECUTIVE SUMMARY

The Upper Hudson River, a 40 mile stretch from Hudson Falls to Troy, NY, is the site of an extensive PCB (polychlorinated biphenyls) remediation project by the U.S. Environmental Protection Agency and General Electric Corporation. Dredging to remove PCB-contaminated sediments began in 2009 and is ongoing with efforts in 2013 and 2014 targeting specific areas of the river in River Section 2, a 5 mile stretch extending from the Thompson Island Dam and Northumberland Dam and portions of River Section 3, between the Northumberland Dam and the Troy Dam. Pools will be prioritized based on the 2013 remediation schedule, in an effort to avoid surveying if remediation is occurring to protect the health and safety of the field crew. The Hudson River Natural Resource Trustees (HRNRT) have been assessing PCB contamination and injuries to natural resources in the Upper Hudson River and have requested a proposal for a pilot study to assess native mussel assemblages in those river reaches targeted to be dredged in 2013 and 2014. This proposal describes an effort to determine population size, relative abundance, size structure, and potential ecosystem services of freshwater mussels in areas targeted to be dredged and un-dredged areas in two reaches (Thompson Island Dam to Fort Miller Dam and Fort Miller Dam to Northumberland Dam) of the Hudson River. This information may be used to inform injury quantification and restoration planning of mussel populations lost due to remedial actions at the Hudson River PCB Superfund Site.

PROBLEM STATEMENT

Quantitative surveys and characterization of native mussel assemblages are lacking for the Upper Hudson River. With PCB-remediation project dredging activities ongoing and hence, mussel communities being removed, opportunities to characterize the mussel assemblage are being lost, as is the ability to estimate potential ecosystem services offered by these animals. We propose to conduct population surveys in two stretches of the Upper Hudson River that are targeted for dredging in 2013 and 2014. These surveys will provide the HRNRT with information to guide their decisions for potential restoration priorities following remediation activities in these reaches of the Upper Hudson River.

BACKGROUND

Freshwater pearly mussels are among the most imperiled groups of animals in North America (Strayer et al. 2004). Almost 300 species of freshwater mussels have been described as endemic to North America, representing the greatest diversity of these mussels in the world. Of these species, 13% are listed as extinct and 66% of the remaining species are ranked as vulnerable, imperiled or critically imperiled (Master et al. 2000). Historically, 51 species of mussels have been described in the state of New York. Currently, 38 species are listed by the New York State Department of Environmental Conservation (NYSDEC) as extinct, threatened, or endangered, or are designated as Species of Greatest Conservation Need (SGCN) (http://www.dec.ny.gov/animals/9406.html). However, since mussel assemblages in many rivers and lakes in NY have never been surveyed and recorded, substantial assemblages may exist, just waiting to be characterized and described. Such is the case for the Upper Hudson River (north of Troy, NY) where there is anecdotal knowledge that abundant mussel assemblages exist, but documentation of their populations and species diversity is extremely limited. With the dredging of PCB-contaminated sediments in the Upper Hudson ongoing, the HRNRT have expressed interest in having surveys of mussel assemblages conducted in 2013.

The diversity and abundance of freshwater organisms provides critical services in these ecosystems. An important group of organisms for the functioning of freshwater systems are the native pearly mussels (Bivalvia: Unionidae). Mussels can be the most abundant benthic organisms in terms of biomass in some systems, often occurring in high-density beds of multiple species (Dame 1996; Strayer et al. 1999; Raikow and Hamilton 2001). Freshwater mussels serve as couplers of nutrient and energy flows between pelagic and benthic communities (Welker and Walz 1998; Raikow and Hamilton 2001; Nalepa et al. 1991; Vaughn

and Hakenkamp 2001), and can be important in removing suspended particles (Newton et al. 2011). In addition, the shells of native mussels provide habitat for other benthic organisms (Sephton et al. 1980; Beckett et al. 1996) and epiphyton (Vaughn and Hakenkamp 2001; Gutiérrez et al. 2003). These services are important for the preservation of clean freshwater ecosystems that provide drinking water and recreational opportunities for residents and visitors to NY. Changes to the diversity, abundance, and long-term viability of native mussel communities may affect the ecosystem services that these communities perform. In the Upper Hudson River, where over 1.3 million square meters of sediment (along with the associated mussel community) have been removed since the project began in 2009, large areas of the native mussel community have presumably already been altered. Our proposed project will quantitatively survey and characterize the potential ecosystem services provided by the existing native mussel community in areas of the river that are targeted to be dredged in 2013 and 2014, relative to areas that are not targeted for dredging. This information could be valuable to guide future restoration efforts of altered areas to pre-dredging levels of mussel diversity, abundance, and ecosystem function.

METHODS

The purpose of this project is to determine the population size, relative abundance, size structure, and potential ecosystem services of freshwater mussels in dredged and un-dredged areas in two reaches (Thompson Island Dam to Fort Miller Dam and Fort Miller Dam to Northumberland Dam) of the Upper Hudson River. Sampling will be restricted to shallow water areas in both reaches (i.e., we will not sample in the main navigation channel). The probabilistic survey will use a stratified random design, with stratification on dredged and un-dredged areas within each reach, for a total of four strata. A simple random selection of 100 to 250 locations will be drawn within each stratum based on GIS coverages. This design provides a comparison of current mussel distribution and abundances between potentially dredged and un-dredged areas in each reach.

Particular care will be given to ensure bias is not introduced from sampling over space through time. We will assign sampling locations to blocks that represent a day of sampling (about 30 sites per day). The sequence for sampling of these blocks will be random, when possible, thus minimizing the potential for bias from sampling point locations in an ordered fashion. Additionally, the design will provide for an unbiased sample if all sampling locations could not be visited in the allotted study period; missing data will be at random (Rogala et al. 2007). Each location will be quantitatively sampled. Predetermined sample sites (comma-delimited file with site coordinates) shall be located in the field using a GPS, and coordinates for the sampled site will be recorded on the datasheet. At each location, field crews shall excavate substrate within a 0.25 meter x 0.25 meter (0.0625 m^2) quadrat to a depth of about 15 centimeters into a 6-mm mesh bag attached to the sampling frame (Figure 1) twice at each site, for a total sampled area of 0.125 m^2. Excavated material will be rinsed through the mesh bag or sieved and transferred to trays to facilitate removal of all mussels. All live mussels will be identified to species, counted, aged (via external annuli count, if possible), and measured for shell length (to the nearest mm using the posterior/anterior axis). The number of fresh dead mussels, with soft tissue and/or clean, shiny nacre, will also be counted as an index of recent mortality.

A subsample of live mussels (~50 individuals of each abundant species), representing a range of size classes, in each stratum will be returned to the laboratory for estimation of wet and dry tissue and shell mass. Representative shell or whole specimens of each species will be retained for species confirmation by colleagues who have expertise in the identification of mussel species in the Northeastern U.S. i.e., Dave Strayer (Cary Freshwater Institute), Lyubov Burlakova (Buffalo State University), and will eventually be curated into the malacology collection at the NYSM. If mussels are returned, they will be placed back into the same pool from which they were collected. At each location we will record the actual GPS coordinate, the water depth at the center of the quadrat to the nearest 0.1 meter, presence/absence of vegetation and substrate type. Substrate type will be determined by subjective tactile/visual methods and be recorded as a percentage of cobble, gravel, sand, silt, and/or clay.

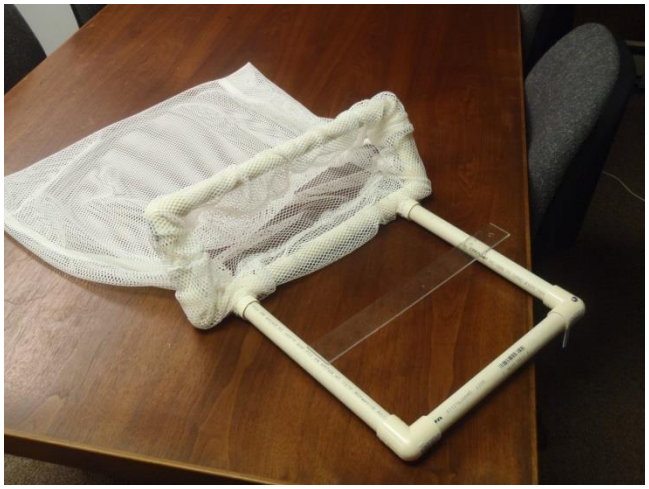

Figure 1: A 0.0625 m^2 quadrat sampler with 6 mm mesh bag attached.

To estimate potential ecosystem services, we will develop a length-mass regression from the subsample of abundant mussels brought into the laboratory. For each abundant species, the mean tissue mass across all sampled individuals in a stratum will be multiplied by the mean stratum abundance to obtain an estimate of the stratum-wide biomass of mussels per square meter as in Newton et al. (2011). Confidence limits will be approximated by multiplying the mean tissue mass by the lower and upper confidence limits around the reach-wide density. To estimate the filtering rate of the community, a filtration rate of 0.5 L per hour per gram dry tissue (Patterson, 1984; Vanderploeg et al. 1995; Pusch et al. 2001) will be applied to observed mussel abundances. Carbon content of mussels (grams per square meter) will be estimated as one half of the mean dry tissue mass (Strayer and Smith 2001). Mean production (grams of carbon per square meter per year) will be estimated from biomass using a production to biomass (P/B) ratio of 0.2 (Nalepa and Gauvin 1988).

Data analysis

Data on population size and relative abundance will be analyzed using survey sampling statistical software (Surveymeans procedure, SAS 2003). These methods accommodate our stratified sampling design and the unequal probabilities across strata (Rogala, et al. 2007). Data on size structure (particularly juvenile mussels) and potential ecosystem services will be analyzed as in Newton et al. (2011).

Quality assurance

To ensure that data from written data sheets are entered accurately into electronic data files, all entered data will be reviewed from the original data sheet by a two person quality assurance team. Chain of custody forms will be completed.

Reporting

The final report of the 2013 mussel survey will include a description of the work effort and results for population size, relative abundance, size structure, and potential ecosystem services for mussels in the river pools sampled including data summaries, calculation of ecosystem services, field notes, and chain of custody forms. Raw data tables and shape files will be provided separately.

Using data to inform recovery efforts

The purpose of this study is to assess the impacts of dredging on the mussel community (and associated ecosystem services) and provide information to guide mussel restoration efforts following remedial actions at the Hudson River PCB Superfund Site. These survey data can be used to inform future restoration activities because they provide resource managers a benchmark of what the mussel assemblage in select reaches may have looked like before dredging. These benchmarks can be used as targets for future restoration activities. For example, the proposed work will identify the ranges in population size, relative abundance, size structure and potential ecosystem services in un-dredged areas of the Upper Hudson River that can be used to help re-establish native mussel assemblages in the dredged areas after remediation. Further details on how the proposed work can inform restoration activities will be developed in coordination with the Trustees.

SCHEDULE

The anticipated period of performance is July 1, 2013 to September 30, 2014, but the schedule is subject to the timing of funding, river water levels and the timing of dredging activities.

- July-September 2013: draft scope of work, create datasheets, establish sampling locations, sample Northumberland Pool
- September-October 2013: sample Fort Miller Pool and process mussels for wet and dry mass
- November 2013-January 2014: enter and proof data and conduct statistical analyses to estimate relative abundance and population size
- February-May 2014: conduct analyses on potential ecosystem services and begin report preparation
- June 2014: draft report to Trustees
- September 2014: final report to Trustees

REFERENCES

American Public Health Association (APHA). 1995. Standard methods for the examination of water and wastewater. American Public Health Association, American Water Works Association, and Water Pollution Control Federation. 19th edition, Washington, D.C.

Beckett, D.C., Green, B.W., Thomas, S.A., and Miller, A.C. 1996. Epizoic invertebrate communities on upper Mississippi River unionid bivalves. American Midland Naturalist 135: 102-114.

Cummins, K.W. 1962. An evaluation of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. American Midland Naturalist 67: 477–504.

Dame, R.F. 1996. Ecology of Marine Bivalves: an Ecosystem Approach. CRC Press, New York.

Gutiérrez, J.L., Jones, C.G., Strayer, D.L., and Iribarne, O.O. 2003. Mollusks as ecosystem engineers: the role of shell production in aquatic habitats. Oikos 101: 79-90.

HRNRT (Hudson River Natural Resource Trustees). 2013. PCB Contamination of the Hudson River Ecosystem Compilation of Contamination Data through 2008. Viewed at: http://www.fws.gov/contaminants/restorationplans/hudsonriver/docs/Hudson%20River%20Status%20Report%20Update%20January%202013.pdf (last visited 2013/07/08)

Master, L.L., Stein, B.A., Kutner, L.S., and Hammerson, G.A. 2000. Vanishing assets: Conservation status of U.S. species. Pages 93-118 in Stein, B.A., Kutner, L.S., Adams, J.S., eds. Precious Heritage: The Status of Biodiversity in the United States. Oxford (United Kingdom): Oxford University Press.

Nalepa T.F., and Gauvin, J.M. 1988. Distribution, abundance, and biomass of freshwater mussels (Bivalvia: Unionidae) in Lake St. Clair. Journal of Great Lakes Research 14:411–419.

Nalepa, T.F., Gardner, W.S., and Malczyk, J.M. 1991. Phosphorus cycling by mussels (Unionidae: Bivalvia) in Lake St Clair. Hydrobiologia 219: 230-250.

Newton, T.J., S.J. Zigler, J.T. Rogala, B.R. Gray, and Davis, M. 2011. Population assessment and potential functional roles of native mussels in the Upper Mississippi River. Aquatic Conservation: Marine and Freshwater Ecosystems 21:122-131.

Patterson, C.C. 1984. Biomass and production of the unionid, *Elliptio complanata* (Lightfoot) in an old reservoir in New Brunswick, Canada. Freshwater Invertebrate Biology 4: 201–207.

Pusch, M., Siefert, J., Walz, N. 2001. Filtration and respiration rates of two unionid species and their impact on the water quality of a lowland river. Pages 317-326 in Bauer, G. and Wachtler, K., eds. Ecology and Evolution of the Freshwater Mussels Unionidae, Springer Press, Berlin.

Raikow, D.F. and Hamilton, S.K. 2001. Bivalve diets in a Midwestern U.S. stream: A stable isotope enrichment study. Limnology and Oceanography 46(3): 514-522.

Rogala, J.T. T.J. Newton, and B.R. Gray. 2007. Documentation of mussel survey methodology deployed in Pool 5 with applications for future poolwide estimates in the Upper Mississippi River. Contract report submitted to Rock Island District of the U.S. Army Corps of Engineers by the U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, September 2007. 12 pp.

Sephton, T.W., Paterson, C.G., and Fernando, C.H. 1980. Spatial interrelationships of bivalves and nonbivalve benthos in a small reservoir in New Brunswick, Canada. Canadian Journal of Zoology 58: 852-859.

Strayer D.L., and Smith, L.C. 2001. The zoobenthos of the freshwater tidal Hudson River and its response to the zebra mussel (*Dreissena polymorpha*) invasion. Archiv fur Hydrobiologie Supplement 139: 1–52.

Strayer, D.L., Caraco, N.F., Cole, J.J., Findlay, S., and Pace, M.L. 1999. Transformation of freshwater ecosystems by bivalves. BioScience 49: 19-27.

Vanderploeg, H.A, Liebig J.R, and Nalepa T.F. 1995. From picoplankton to microplankton: temperature-driven filtration by the unionid bivalve *Lampsilis radiata siliquoidea* in Lake St. Clair. Canadian Journal of Fisheries and Aquatic Sciences 52: 63–74.

Vaughn, C.C. and Hakenkamp, C.C. 2001. The functional role of burrowing bivalves in freshwater ecosystems. Freshwater Biology 46: 1431-1446.

Welker, M. and Walz, N. 1998. Can mussels control the plankton in rivers? - a planktological approach applying a Lagrangian sampling strategy. Limnology and Oceanography 43: 753-762.

APPENDICES

Appendix 1: Health and Safety Protocol

Hudson River Mussel Surveys 2013
SOP: Health and Safety Plan

The success of any field sampling program is a direct result of careful and complete planning and organization. The safety of all field personnel is the most important factor to consider in planning all aspects of a study. This document describes the roles that each team member plays in completing a safe and productive field season.

- Daily Work Plan: The work plan for the day will be discussed with the entire crew at the beginning of each work day. Items to discussed include:
  - Sites to be sampled and where to begin sampling.
  - Assessment of potential hazards, weather, dams, current, etc.
  - Check two-way radios for batteries and that all radios (3) are powered up.
  - Presentation of appropriate data sheets and maps to each crew.
    - The site marking crew (NYS-DEC boat and crew) will evaluate maps, data sheets, and daily site plan.
    - The dive boat survey crew will assess safety equipment on the boat (dive flag, anchor), data sheets, maps, and site plan.
    - The mussel assessment crew will set up tables and equipment in a safe location, prepare appropriate data sheets, and keep the shore site organized.

- Personal flotation devices will be provided, appropriately adjusted, and worn by personnel while in sampling watercraft.

- Diving Safety: Since the freshwater mussel surveys require underwater sampling, only certified SCUBA divers will be performing dives. Shallow, wadable sites may be sampled by non-SCUBA-certified staff (depths less than 1 m).
  - Site marking boat (NYS-DEC boat) staff:
    - Do not approach the dive boat when the diver is under water, but will wait until the diver surfaces and is holding on to the dive boat.
    - Alert dive boat staff to potential hazards ahead including water depth, current, fallen trees, etc.
  - Dive boat staff: There will be 3 personnel in the dive boat, including one diver and 2 boat staff. Each staff member in the dive boat will receive training prior to actual field sampling to ensure that the boat is operated in a safe manner and that the dive tender(s) is knowledgeable and prepared.
    - Once the diver is in the water, a dive safety flag will be presented and visible on the boat or in the water at all times until the diver out of water.
    - Both members of the boat crew will remain alert and aware of the diver's location while underwater. Keeping distractions away from the boat. Someone's eyes should ALWAYS be on the site marker and air bubbles. Record data only when the diver has surfaced.

- Diver:
  - All diving equipment must be in excellent operating condition and have undergone annual servicing. The diver must be SCUBA certified and in good physical condition. If in doubt at any point during the day, don't dive.
  - Perform performance and safety checks of all equipment at the start of each day and periodically throughout the day.
  - Do not allow the air tank to go below 500 psi. For a full day of surveys, change out the air tank at lunchtime.
  - Special safety precautions will be followed when diving each site:
    - The system we are using to locate and mark sites provides a good system for diver safety. When descending at a site, the marker line will serve as a guide to the marker anchor where the grid quadrat will be placed. The marker line will be kept between the diver's arms as a life-line to the surface. At any point, a sharp tug on the line will alert the dive tender in the boat and the diver will be retrieved with the marker line.
    - While slowly descending, the diver will maintain a horizontal position and be scanning the area for potential hazards.
    - Diving depths will generally be 2 to 6 m, and rarely will depths greater than 8 m be encountered. Sites will be excluded from sampling if their depth is not safe for solo, tended, diving. These relatively shallow sampling depths are safe for repetitive diving.

DIVER CHECKS:

- Inspect the Cylinder(s) for cracks, dents, gouges, or defective valves. Check O-ring.
- Verify current hydrostatic test and visual inspection, on all cylinders to be used.
- Gauge Cylinder (s) Charge if necessary. (Reserve UP) Check for leaks. Shut cylinder valve.
- Inspect regulator assembly. Attach to cylinder. Open cylinder valve. Verify operation by breathing regulator.
- Inspect Face mask
- Inspect BC.
- Inspect all other equipment. Ensure all rubber in good condition.
- Knife is sharp.
- Adequate weight.
- Lay out all equipment ready for use

Appendix 2: Chain of Custody Form

NYS Museum Field Research Laboratory

51 Fish Hatchery Road
Cambridge, NY 12816

Hudson River Mussel Survey 2013: Chain of Custody

SAMPLE RECORD OF FIELD COLLECTED SAMPLES

Field Collection Date:
Collection Location:

Quad Site #	Quad Site #	Quad Site #	Notes

Appendix 3: Hudson River 2013 Data Sheet

Quad #	H_2O depth (m):		Northing:	Easting:	Veg present in quad: yes no	
Species	Length (mm)/Age (yrs)	# FD Shells	Species	Length (mm)/Age (years)	# FD Shells	
	/			/		Substrate %
	/			/		Clay_____ Silt_____ Sand ___ Gravel____ Cobble___ Boulder ___ Bedrock ____ Shells _____ Veg_____ Det/Log_____
	/			/		
	/			/		
	/			/		
- -	/		- -	/		

Notes:

Appendix 4: Dive Boat Data Sheet

Upper Hudson River **Date:** **Page ___of ___**
Crew:

Quad #		H_2O depth (m):
Substrate %		Veg present in quad?
Clay	-	No
Silt		Yes
Sand		Type:
Gravel		
Cobble		
Boulder		Notes:
Bedrock		
Vegetation		
Detritus		
Logs		
Shells		

Appendix 5: Protocol for Sampling Native Mussels in Upper Hudson River

Population estimates

Download UTM coordinates provided by USGS into GPS. Discuss the sampling plan for the day and record the date and team member names on top of appropriate data sheets.

GPS Boat Team:

- Navigate boat (or wade) to predicted GPS coordinate
- Record actual GPS coordinate on data sheet
- Place labeled yellow marker at site, taking up as much slack in the line as practical.

Dive Boat Team:

- Approach the marker location and place anchor
- Shut off motor so diver can descend along the marker rope to the anchor.
- Place the 0.0625 m^2 quad on the river bottom next to the marker anchor location.
- Diver takes visual/tactile assessment of the substrate in the quadrat and excavates the substrate within the quadrate to a depth of ca. 15 cm and places it into the attached 6 mm mesh bag. Repeat excavating a second quadrat area into the same sample bag for a total of 0.125 m^2 sample area.
- The boat team records on data sheet the quadrat number, water depth to the nearest 0.1 m, substrate type, and presence and type of submergent vegetation present at each location before moving on to next quadrat.
- Raise the sample bag up and down in the water to remove fine sediments before emptying contents into a bucket. Place the quadrat number label on the bucket and remove the quadrate number label from the yellow marker and place in the bucket.
- Hand off buckets to GPS boat to transfer to the Mussel Processing Team.

Mussel Processing Team:

- Remove all freshwater mussels from the bag and sort into alive and fresh dead (fresh dead mussels will contain soft tissue and a clean/shiny nacre).
- Record the number of live and fresh dead (FD) individuals of each species; record on data sheet.
- Using calipers, measure shell length as the greatest anterior-posterior distance that is perpendicular to the hinge line (make sure not to crush the new periostracum that has not calcified); record on data sheet.
- Count the number of external annuli; record on data sheet. If the periostracum is badly weathered such that annuli cannot be easily visualized, do not age the individual, but make a note in the comments section why this mussel wasn't aged.
- Voucher representative specimens of each species for independent verification at a later date.

Length-mass regression

While sampling for population estimates (above), retain a total of about 50 individuals of each abundant species from multiple dredged and un-dredged areas (i.e., n=50 dredged areas, n=50 un-dredged areas). Place mussels into an ice-filled cooler in labeled ziplock and transport back to the laboratory. In the laboratory, estimate wet and dry tissue and shell mass following AHPA et al. (1995).

Archival of mussels for PCB analyses

While sampling for population estimates (above), retain individuals of each abundant species from multiple dredged and un-dredged areas. Place mussels in labeled ziplock bags into an ice-filled cooler and transport back to the laboratory to be placed into the chest freezer (-20ºC).